American Research Journal of Agriculture

Volume 8, Issue 1, 1-9 Pages
Research Article | Open Access
ISSN (Online)- 2378-9018
DOI : 10.21694/2378-9018.22001

AMERICAN RESEARCH JOURNALS
An Academic Publishing House

Dynamics of Land Use and Land Cover Change Using Geospatial Techniques in Sampla Town of Rohtak District, India

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ABSTRACT

The technique to identify how the pattern of a particular landuse/land cover (LULC) has evolved using various tools and methodologies is accessible through geospatial techniques. LULC is an important field of research in geography since it shows how the landuse of a region has been changing in time and space. It requires precise data on the LULC change that has occurred in that region, especially in this era of new urban and industrial developments. The LULC study was conducted in Sampla, a small town in the Rohtak district of Haryana, India. Due to the continuous growth of the National Capital Region(NCR), Delhi, Sampla, and its surrounding areas have seen a significant land use change. Thus, Sampla is an example of one such town where landuse changes are continually undergoing due to its proximity to India's capital. Therefore, the present study aims to analyze the LULC changes in Sampla over two decades using geoinformatics techniques like LULC, Change matrix, Image Difference, vector and raster data analysis. The analysis starts by constructing three LULC layers for two decades (2001,2011, and 2021). Results of the study show that Sampla has undergone massive change in the last two decades. Built up area has increased manifold, and an increase in the area under barren land and wasteland is also observed. An increase in the area covered by water bodies has led to urban flooding within the town.

KEYWORDS: *Urbanization, Landuse/ Landcover, Maximum Likelihood technique, Change detection technique,*

INTRODUCTION

Around the world, the human-induced alteration of Earth's surface is referred to as land use/land cover change (LULCC). The extent, severity, and rate of LULCC are much greater now than they were in the past despite the fact that humans have been altering land for thousands of years in order to obtain livelihoods and other necessities (Mishra et al. 2021, 2022). These changes are driving forces for local, regional and global level unprecedented changes in ecosystems and environmental processes. Thus, LULC changes play an important role in the study and analysis of global changed scenario today as the data available on such changes is essential for providing critical input to decision-making of ecological management and environmental planning for future (Zhao et al. 2004; Dwivedi et al. 2005; Erle and Pontius 2007; Fan et al. 2007, Mindal et al. 2022; Aditi, et al 2022). Changes in landuse/landcover (LULC) have a direct impact on the sustainability of environmental resources and the ecological scheme's equilibrium (Verburg et al. 2004).

Change detection identifies geographic changes in multi-temporal satellite pictures caused by human-caused or natural phenomena. The LULC change detection investigations are critical in the current context since human activities are changing the face of the world dramatically. Remote sensing satellites gather satellite pictures utilizing a variety of distinct areas of the electromagnetic spectrum; each of these portions has a unique set of applications but change detection studies account for a significant percentage of it. The purpose of this study is to conduct a cursory examination of different change detection algorithms used in digital image processing-based tasks. Over the past few decades, the understanding of land-use/land-cover change has evolved from simplicity to realism and complexity. Early studies focused mostly on the physical side of the change, but later research agendas focused on global environmental change. LULC change studies are essential as land cover changes have a snowballing impact on other phenomena, even weather and climatic fluctuations are linked up with these changes. In mid1970s, it was recognized that land cover change modifies surface albedo and thus surface atmosphere energy exchanges, which have an impact on regional climate (Otterman, 1974; Charney and Stone, 1975). Much broader range of impacts of land-use/cover change on ecosystem, goods and services were further identified. Of primary concern are impacts on biotic diversity worldwide (Sala et al. 2000), soil degradation (Trimble and Crosson, 2000), and the ability of biological systems to support human needs (Vitousek, 1997; Praveen, B. 2017).

The kind, magnitude, and location of land use change can be quantified using multi-spectral and multi-temporal data that satellite remote sensing provides. GIS, on the other hand, offers a versatile environment for viewing, storing, and analyzing digital data that is essential for change detection. For land use change detection, RS data from various sensors such as Landsat MSS, TM, ETM, SPOT HRV, IRS and AVIRIS are being used, and to demonstrate changes in multi-temporal approach, two or more sensors are considered (Mertens and Lambin, 2000, Roy and Tomar, 2001, Yang and Lo, 2002, Baskent and Kadiogullari, 2007 and Shalaby and Tateishi, 2007). In the recent times Unmanned Aerial Systems(UASs) are also used extensively for land based studies (Mishra and Rai, 2020)

Several approaches, including object pixel-based classification in LULC change mapping, cross-correlation analysis, image differencing, post-classification comparison (PCC), and image fusion-based LULC change detection, have been adopted and utilized to identify LULC changes (Yang et al., 2017; Birhanu et al., 2019). Remote sensing is extremely useful in detecting changes in land use and land cover since it can provide a synoptic view of the entire globe, spanning large to small scale areas and also capturing electromagnetic spectrum in ranges other than the visible spectrum. Furthermore, it is relatively simple to extract information from the remotely sensed image because to the electromagnetic spectrum's capacity to be divided into different bands. The necessary data in a GIS environment in combination with Global Positioning System (GPS) is a powerful tool in analyzing the changes to further make the policies for environmental management.

Thus, the land use land cover (LULC) change detection using geoinformatics techniques is important for decision makers to arrive at the conclusions and make suitable policies for the conservation of our natural resources and further for the stability of our ecosystem. It can be used to frame effective guidelines for land conservation, management of marine resources, ecological restoration and sustainable development. The major purpose of this study is to outline and quantify the land use elements that contribute to the conversion of each land use class. Sampla is a steadily developing town lying in Rohtak District of Haryana. Being situated along the National Capital Region area, Sampla have proved to be a suitable site for residential establishment in affordable prices. But this is also leading to changes in its landuse landcover distribution pattern. To analyze its change and to find out the applicability of various change detection techniques an initiated is taken to create LULC maps of the concerned area for the year 2001,2011 and 2021. An effort is made to apply the change detection techniques with the generated data and to find out whether the data generated can further be beneficial for urbanization and land use policies in future.

STUDY AREA

Sampla is a municipality and town in the Haryana state in northern India's Rohtak district, it is also tehsil headquater of Sampla tehsil. The spatial extension of Sampla is between 28°45'48.40"N and 28°47'30.73"N to 76°45'32.68"E and 76°48'20.64"E . It falls along NH9 which connects Rohtak to Delhi. The state capital of Sampla is Chandigarh which is located around 219.8 km away from Sampla. It is 44.4 km away from the capital of India i.e Delhi. The town constitutes of 13 wards for which elections are held every 5 years. According to census 2011, the town has a population of 103,263 which includes 55,964 males and 47,299 females. Kheri Sampla (2 km), Nayabans (3 km), Gijhi (4 km), Dattaur (5 km), Bhesru Khurd (6 km) are the nearby Villages to Sampla. Sampla is surrounded by Bahadurgarh Tehsil towards South, Kharkhoda Tehsil towards East, Rohtak Tehsil towards North, Beri Tehsil towards West.

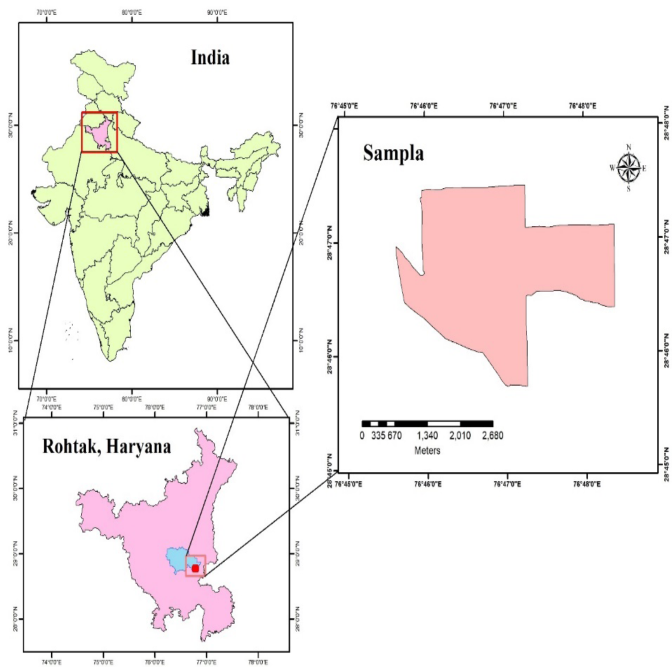


Figure 1. Location of Study Area: Sampla, Rohtak District, Haryana, India

DATABASE AND METHODOLOGY

Data collection and image classification

Initially, physical land surface qualities like built-up area, vegetation area, agricultural area, and water bodies were predominantly identified using LULC data (Table 1). The Sampla town was covered by Landsat-based images with a spatial resolution of 30 m 30 m that were gathered in 2001, 2011, and 2021 using Landsat 5 (MSS) and Landsat 8 (OLI), as shown in Table 2. Landsat images were chosen for March as Landsat images are mostly accurate and cloud free in March. These images were taken from the website of the United States Geological Survey (USGS) (https://earthexplorer.usgs.gov). ERDAS Imagine 2014 was used for radiometric correction, layer stacking, and mosaicking (Rahman et al., 2017). Calibration of the minimum mappable unit (1:25,000) was performed at each stage of the multiple LULC classification and mapping processes. Clipping was accomplished by extracting the picture based on the research region using the extract by mask tool in ArcGIS 10.5 software. Following pre-processing, a supervised classification approach (maximum likelihood algorithm) based on field information was used to determine the LULC classes for the years 2001, 2011 and 2021 utilizing software such as ERDAS envision 2014 and ArcGIS 10.5. The produced LULC maps were statistically analyzed to determine the LULC changes in the Sampla town using ArcGIS 10.5 software. Due to the spectral, geographical, and temporal resolutions of these LULC pictures, they supplied important information for mapping and city planning. Landsat 5 with a spatial resolution of 30 meters in 2001 and 2011, and Landsat 8 OLI, having a resolution of 30 meters for 2021, were collected via the USGS earth explorer. The data was obtained in the Geotiff format, which is pre-grounded in UTM zone 43N using the WGS 84 datum (Table 1).

Table 1. Specification of Satellite data used

S.no	Satellite	Sensor	Row/Path	Year	Band used	Resolution	Wavelength (µm)
1.	Landsat 5	MSS	147,040	2001, 2011	1	30m	0.45 - 0.52
					2	30m	0.52 - 0.60
					3	30m	0.63 - 0.69
					4	30m	0.76 - 0.90
2	Landsat 8	OLI	147,040	2021	2	30m	0.450 - 0.51
					3	30m	0.53 - 0.59
					4	30m	0.64 - 0.67
					5	30m	0.85 - 0.88
					6	30m	1.57 - 1.65
					7	30m	2.11 - 2.29

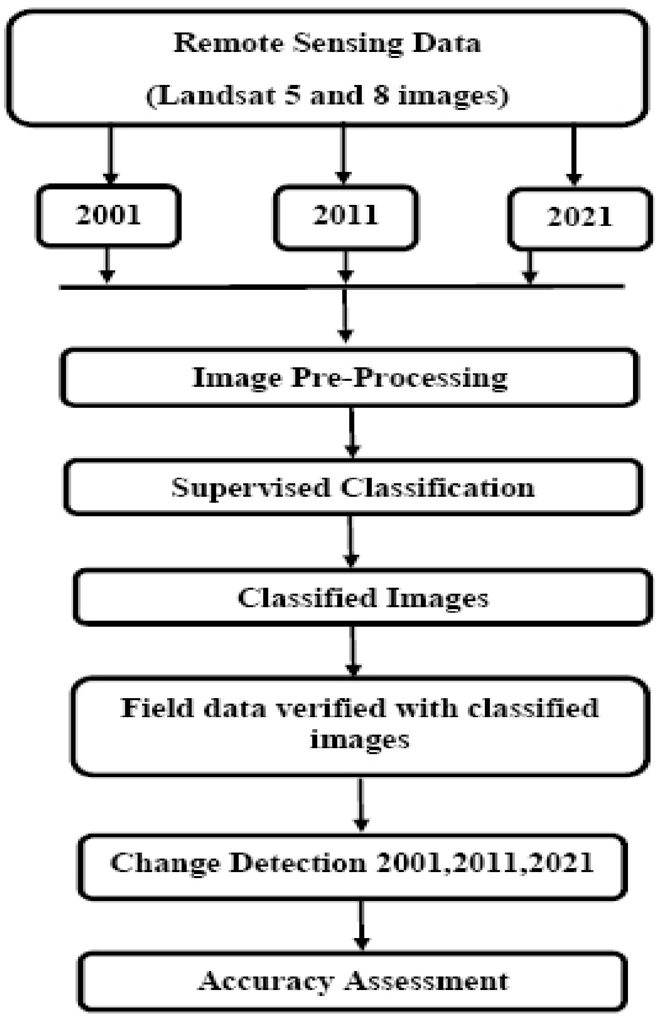


Figure 2. Methodology for Landuse/Landcover

Pre-Processing

After classification, a pre-processing method was used. Pre-categorization enhances the output while also assists in its authentication. This study used class recoding and accuracy testing to finish the pre-processing stage. Recode renumbers any or all classes, resulting in the creation of a new theme-based raster layer with the new class numbers. Using the accuracy evaluation, we may compare individual pixels in the theme raster layer to known-class reference pixels. This is a method for comparing the categorization to the ground truth data in a method-based pattern. The accuracy of the current study was determined using Google Earth as the ground truth data.

Analyses based on raster data

Raster analysis is used for change detection technique in which each pixel of a land use land cover (LULC) map is examined over two time periods by overlapping both images. By leveraging "from, to" information, a pixel-based comparison approach was employed in the current research to create change information on a pixel-by-pixel basis and therefore more effectively understand the changes.

Analyses of vector data

Geometric objects such as a point, line, or polygon are subjected to vector data analysis. The AND, OR, and XOR Boolean connectors are used to analyze the vector data. The While connection was used to identify locations that remained unchanged, while the XOR connector was used to indicate places that changed in this study.

Image Distinction

Image differencing is a type of image processing that is used to compare and contrast two images. The difference between two raster images is calculated by deducting each pixel from each image and creating a new image. To generate the final edited image in this work, both photos were eliminated.

Classification of land cover

The images were processed and classified correctly. The maximum likelihood supervised classification technique was used in this research work, and it is based on the hypothesis that the distribution of pixel values within each class can be described nearly identically by a normal distribution whose variables are the digital values in each of the image's spectral bands. Most of the training pixels in a class have similar values, therefore they are built to form a stretched cluster over the space. The number of training pixels with the same value reduces as one proceeds out from the cluster's centre. The MXL classifier considers the spectral response contour as well as the variance and covariance of the grouping when classifying unknown pixels. Between 2001 and 2021, a LULC map for five classes was produced using these techniques. (Table 2)

Table 2. Land use land cover scheme of the study area

Sr.no.	Class Name	Description
1	Built up	It consists of industrial, transportation, residential, commercial, and residential infrastructure
2	Vegetation	It includes forest area and grassland.
3	Agriculture	The land covered with agricultural crops.
4	Water bodies	Permanently submerged areas, such as those created by dams and ponds,
5	Barren Land	Areas with little or no vegetation, including bare rocks

Detection of LULC change

When the spectral properties of several LULC types at one area vary over time, change detection is the process of identifying temporal effects caused by these changes (Gidado et al., 2018, Mishra, et al., 2020, 2021). Through repeated observation, change detection was utilized to identify alterations in an object's or phenomenon's condition across time. Data from various satellites were combined, or data from various sensors of the same type were compared, to perform change detection. Data collection, pre-processing, supervised classification, accuracy evaluation, and change detection analysis were all used in the LULC change detection analysis. Change detection statistics for the years 2001, 2011 and 2021 were generated for this investigation. By dividing recorded data by the percent of change, it was possible to determine the trend of variation.

RESULTS AND DISCUSSIONS

The current research was started with the goal of determining the applicability of various RS and GIS techniques in LULC change detection. Furthermore, an effort was made to analyze Ghaziabad's land use land cover changing pattern. Satellite data were obtained from the USGS to achieve these goals. Various vector and raster data were created, interpreted, and analyzed in detail. Landsat7 and Landsat8 images were downloaded, and a land use land cover map was created using the maximum likelihood supervised classification technique.

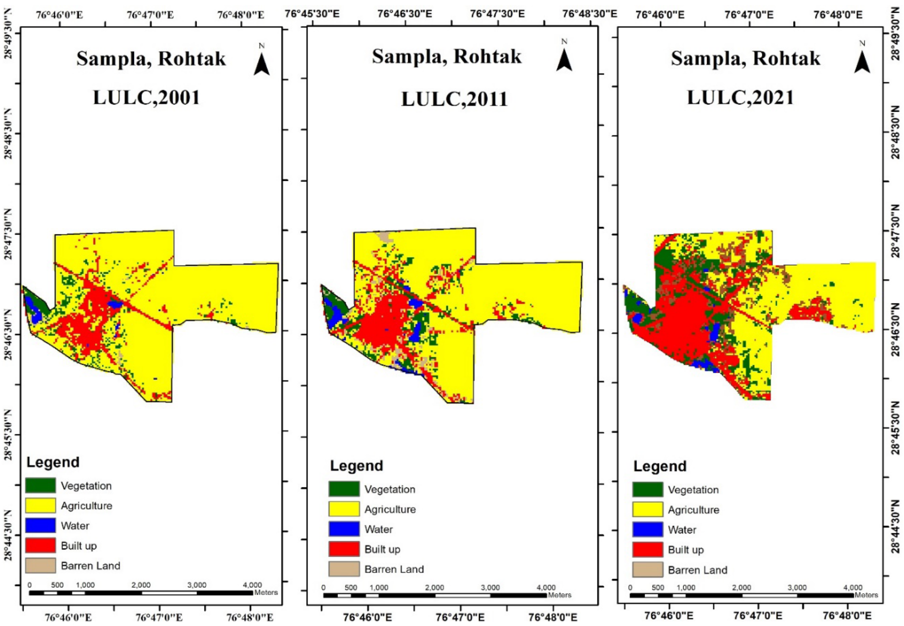


Fig 3. Lulc of 2001,2011 and 2021

Table 3. LULC statistics of the study area for 2001, 2011 and 2021

LULC	2001		2011		2021	
	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)	Area (Km^2)	Area (%)
Agriculture	**6.65**	**80.41**	**5.80**	**70.13**	**3.71**	**44.86**
Barren Land	**0.03**	**0.36**	**0.30**	**3.62**	**0.77**	**9.31**
Built Up	**1.06**	**12.81**	**1.33**	**16.08**	**2.30**	**27.81**
Vegetation	**0.43**	**5.19**	**0.63**	**7.61**	**1.33**	**16.08**
Water	**0.10**	**1.20**	**0.22**	**2.66**	**0.16**	**1.93**

Source - Calculated from LULC map

The final classified landuse maps were shown in Figure 2. The change matrix for different areas from one class to another between the assigned dates were depicted in Table 3. Furthermore, the total size of LULC was shown in Kilometer, and the fraction of each LULC class between different time periods is shown in Table 2. A supervised classification method reveals general decreases in agricultural land and an increase in settlements and vegetation land between 2001, 2011 and 2021. The findings of the study area revealed agricultural land changes in land use and land cover in the study area 6.65(80.41%), 5.80(70.13%) and 3.71(44.86%) during the years 2001, 2011 and 2021 respectively. For these years, the study area, representing agricultural land, is converted to settlements 1.06(12.81%),1.33(16.08%) and 2.30(27.81%) respectively. These areas have significant urbanization and industrialization growth that have a direct impact on the agriculture crops and landuse classes in the area. In the years 2001,2011 and 2021 the vegetation also observed an increase from 0.43(5.19%), 0.63(7.61%) and 1.33(16.08%).

The previous good accuracy of three thematic maps of LULC were based on the supervised classification approach is agreed upon in this research. During the years 2001 and 2011, the findings yielded overall accuracies of 92,95 percent and 90 percent, respectively; overall, the kappa values were > 0.90. Table 4 shows that the area covered by agriculture is diminishing, and that most of that land is being transformed into settlements, since the area under settlement has obviously increased. A unique phenomenon can also be seen in the current research is that there has been a peculiar change in area covered by water bodies. A change matrix may be used to properly depict the changing pattern of the different land cover classifications. The change matrix computes the area-wise change in land cover over time. Table 4 depicts the area-wise change of each land cover using a change matrix.

Table 3 (a). Change matrix between 2001 and 2011

		LULC 2011					
	Class	**Agriculture**	**Barren Land**	**Built up**	**Vegetation**	**Water**	**Grand Total**
LULC 2001	Agriculture	**5.81**	5.81	5.81	5.81	5.81	29.03
	Barren Land	0.30	**0.30**	0.30	0.30	0.30	1.50
	Built Up	1.34	1.34	**1.34**	1.34	1.34	6.69
	Vegetation	0.63	0.63	0.63	**0.63**	0.63	3.17
	Waterbody	0.22	0.22	0.22	0.22	**0.22**	1.10
	Grand Total	**8.30**	**8.30**	**8.30**	**8.30**	**8.30**	**41.51**

Table 3 (b). Change matrix between 2011 and 2021

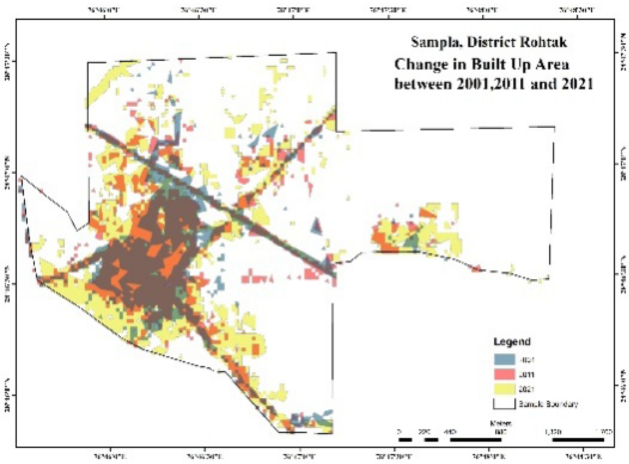
		LULC 2021					
	Row Labels	**Agriculture**	**Barren Land**	**Built Up**	**Vegetation**	**Waterbody**	**Grand Total**
LULC 2011	agriculture	**3.72**	3.72	3.72	3.72	3.72	18.59
	barren land	0.78	**0.78**	0.78	0.78	0.78	3.89
	built up	2.30	2.30	**2.30**	2.30	2.30	11.50
	vegetation	1.34	1.34	1.34	**1.34**	1.34	6.69
	water body	0.17	0.17	0.17	0.17	**0.17**	0.83
	Grand Total	**8.30**	**8.30**	**8.30**	**8.30**	**8.30**	**41.51**

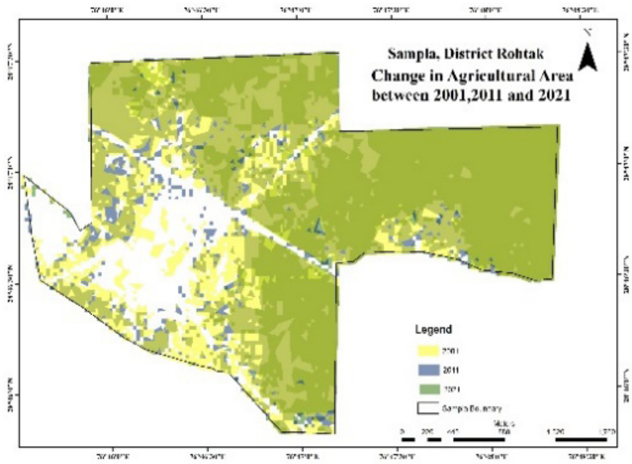
Table 3 (c). Change matrix between 2001 and 2021

		LULC 2021					
	Class	**Agriculture**	**Barren Land**	**Built Up**	**Vegetation**	**Waterbody**	**Grand Total**
LULC 2001	Agriculture	3.72	3.72	3.72	3.72	3.72	18.59
	Barren Land	0.78	0.78	0.78	0.78	0.78	3.89
	Built Up	2.30	2.30	2.30	2.30	2.30	11.50
	Vegetation	1.34	1.34	1.34	1.34	1.34	6.69
	Waterbody	0.17	0.17	0.17	0.17	0.17	0.83
	Grand Total	**8.30**	**8.30**	**8.30**	**8.30**	**8.30**	**41.51**

LULC CHANGE DETECTION

The research of analyzing land use and land cover over a 20-year period (from 2000 to 2021) has been completed; the divided pictures mentioned were used to determine changes in land use and land cover for three time series data (2001, 2011, and 2021). (Figures 3a and 3b). Tables 3 for supervised classification show the situation of landcover classes between the assigned time series, the land-cover classes' change matrices with the variation in area by hectare and percentage. The primary goal of this study is to determine the applicability of remote sensing and GIS in change detection. As a result, multiple change detection approaches were used. Following the generation of land use land cover pictures for 2000 and 2020, the images were overlaid and pixel-by-pixel change was examined. The maps were made by overlaying each relevant land cover class while leaving the rest of the classes as hollow and increasing transparency. According to the categorization, the land cover classifications that have witnessed the most change include agricultural, settlement, built up, and vegetation. A pixel-based overlay approach was utilized to determine the modified and unaffected area of each land cover class. Figure 4 depicts the outcome of the latter. Vector data analysis was also used to determine the changed and unchanged areas. Vector data analysis makes use of geometric objects such as points, lines, and polygons. The precision of analyses is determined by the precision of these items in terms of position and form. Vector data utilities in ArcGIS include buffer, union, intersect, and symmetrical difference. Dissolve, update, and so forth. Some of these tools make use of bullion connectors like as and, or, and X or. Vector data analysis has shown to be one of the most effective but easy techniques for visualizing changes over time. Vector data analyses are made up of several tools that operate on the Boolean operators. Images must be translated into shapefile format for vector data analysis, which is then utilized for many sorts of studies. Vector data analysis methods such as intersect, symmetrical difference, select, and clip were utilized in this study to demonstrate the changes of key land cover classes. Figure 4 depicts the ultimate result. Image differencing algorithms are based on multivariate statistics and identify changes in a variety of ways. Imaging Differencing categorizes cells based on spectral changes between before and after events (Myint.et.al 2008). Image differencing involves subtracting co-registered pictures from two separate dates, followed by the application of a threshold value to obtain an image that depicts changes in land use and land cover. Threshold levels are often chosen based on a standard deviation value, as previously described. A lower standard deviation may result in more inclusion of no change (Fig 3). Ideally, the suitable threshold should be chosen based on the accuracy of classifying pixels as change or no change. The mean plus a number of standard deviations may be used to establish the threshold values for change/no change, or they can be performed interactively using a monitor and operator-controlled image processing. Level slicing software is available. Although this is a simple technique, it merely finds altered regions rather than defining the kind of changes from one class to another.





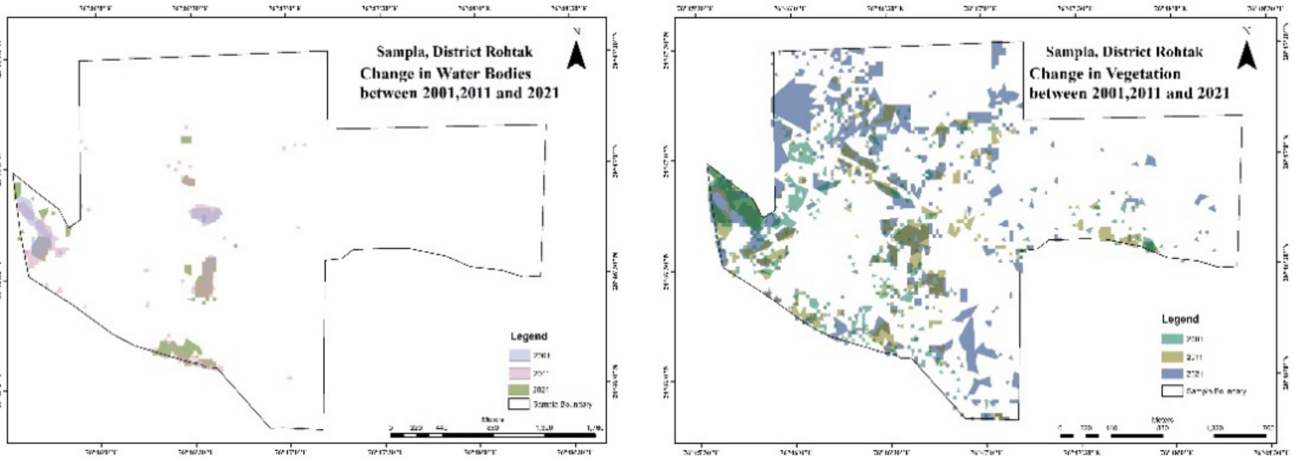


Figure 4. Change in (a). Built up, (b). Agriculture, (c). Waterbody, (d). Vegetation

The town of Sampla has seen significant changes in terms of built up of the area. In 2011, small clusters of settlement have been developed around the town mainly near the core establishments of the area which is prevalent there since older times. These areas in the central and south east part of the town have remained unchanged through the decades. The data of year 2021 reveals that the built up widening in different parts of the town reaching up to northern and southern outskirts. The major roads running through the area have, however, remained unchanged. A notable change in the town is the establishment of a colony in the east namely Chotu Ram Nagar which emerged from a small cluster in 2001 to a well settled colony in 2021 and is still growing.

While the agriculture was limited to only few areas in the town in 2001, it saw noteworthy growth in 2011 and by 2021, the significant part of the town was seen covered in agriculture. The area under the agriculture has only increased in these two decades. It spreads right upto the outskirts of the town. The only area totally free from agriculture is the residential cluster located in the central part of the town. This major advancement in the agricultural cover is mainly attributed to exposure of farmers to the new agricultural techniques and irrigational facilities by the local government.

Number of small ponds that were prevailing in the town in 2001and 2011 have perished in the decade's time. Few major water bodies in the central and the western region of the town have however remained unchanged. A bridge was located in the central pond but after the rainfall in 2021 the partition broke causing flood in the nearby regions and affecting the houses in that part of the town. Flooding was accompanied by other problems like deposition of waste near the banks brought by the flood water causing unhygienic and bad living conditions for the residents of the area.

The overall vegetation of the town has seen a positive growth in the two decades. The town had few clusters of vegetation in 2001 which increased marginally in 2011 and by a substantial amount in 2021. Vegetation in the western part of the region has remained unchanged. One major concern is that few areas that had vegetation cover in 2001 has no vegetation in 2011 like in north western part of the town and similarly few areas under vegetation cover in 2011 have little traces of the same 2021 like the eastern part of the town.

To validate the accuracy of the work a field level survey was also done. The places having the maximum changes within these years were scanned in the field too. Photographs of these changes were also clicked to confirm validity of the work. Some of the field level photographs are shown in the figure 4.

Fig 5. Field Photograph of different locations of Sampla

A). The unchanged barren land in the extreme west of Sampla, B). The barren land along the road., C). The unchanged highway crossing the city, D). The stagnant water near the pond area in the center of the city.

CONCLUSION

For analysis and changes in the land-use and land-cover classifications, remote sensing and GIS technologies were combined. In this study, the supervised classification approach was utilized to identify land-use types using field data as a reference. In this research, two standard classification techniques (MLC method) were used. A supervised classification method reveals general decreases in agricultural land and an increase in settlements and vegetation land between 2001, 2011 and 2021. The findings of the study area revealed agricultural land changes in land use and land cover in the study area 6.65(80.41%), 5.80(70.13%) and 3.71(44.86%) during the years 2001, 2011 and 2021 respectively. For these years, the study area, representing agricultural land, is converted to settlements 1.06(12.81%),1.33(16.08%) and 2.30(27.81%) respectively. These areas have significant urbanization and industrialization growth that have a direct impact on the agriculture crops and landuse classes in the area. In the years 2001,2011 and 2021 the vegetation cover also observed an increase from 0.43(5.19%), 0.63(7.61%) and 1.33(16.08%). The supervised classification approach, on the other hand, has shown to be an excellent classifier, with an overall accuracy of up to 92 percent. Using this method, it was discovered that Sampla has undergone several alterations. Waterbodies, Vegetation, agriculture and built up are the land cover classes that have witnessed the most change. In the year 2001, most of the area was covered by agriculture, which is diminishing severely in the recent times due to increase in settlement. Settlement is the succeeding land cover type that has witnessed the greatest modifications. By the year 2021, most of the agricultural land had been turned into settlement, resulting in an increase in habitation and a decrease in agricultural land. These technologies enable change detection in a significantly shorter amount of time, at a lower cost, and with more precision. More research is needed to investigate the water source and supply in the study region, as well as to correlate agricultural and drinking water needs with the time to offer an overall environmental picture of the study area.

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Citation: Rajender Singh, Parveen Bano, Prabuddh Kumar Mishra, "Dynamics of Land Use and Land Cover Change Using Geospatial Techniques in Sampla Town of Rohtak District, India", American Research Journal of Agriculture, Vol 8, no. 1, 2022, pp. 1-9.